HST Auroral Campaign Observations of Jupiter and Saturn enabled by the CDPP/AMDA and IVOA/Aladin tools

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ABSTRACT

The Plasma Physics thematic node of IDIS (http://europlanet-plasmanode.oeaw.ac.at/) is established in close cooperation between the IWF Graz (http://www.iwf.oeaw.ac.at/) and CDPP Toulouse (http://cdpp.cesr.fr/). These last years, CDPP has developed a new service, AMDA (Automated Multi-Dataset Analysis, http://cdpp-amda.cesr.fr/), which is a web-based facility for on line analysis of space physics data (heliosphere, magnetospheres, planetary environments) coming from either its local database or distant ones, such as the Cassini/MAPSKP, VEX/MAG at IWF/Graz or the CDAWeb (http://cdaweb.gsfc.nasa.gov/).

These last years, a large campaign of remote high resolution imaging of Jupiter and Saturn aurorae has been undertaken using the Hubble Space Telescope, in association with in situ measurements of local solar wind and magnetospheric plasma conditions using several different spacecraft (including Galileo, Cassini and New Horizons). The coordinated scientific exploitation of all these data is a major technical challenge, since it requires accessing heterogeneous data from diverse origins to perform an integrated study combining different software tools appropriate for the analysis of the solar wind, magnetospheric, ionospheric and atmospheric phenomena observed.

In the context of our IDIS activities, we will detail our prototype service connecting the CDPP/AMDA service with the IVOA (http://www.ivoa.net/) tool Aladin (http://aladin.u-strasbg.fr/), which is an interactive software that enable the user to visualize digitized astronomical images of Jupiter and Saturn aurorae in combination with solar wind and magnetospheric data reachable via AMDA.

INTRODUCTION

These last years, several campaigns of ground- and space-based high resolution multi-wavelength spectroscopy and imaging of Jupiter and Saturn auroral emissions have been undertaken (e.g., IUE, HST, Chandra, XMM, ROSAT, IRTF, CFHT), in association with remote auroral observations and in situ measurements of local solar wind and magnetospheric plasma conditions using several different spacecraft (e.g., Galileo, Cassini, New Horizons), as illustrated in Figure 1. The coordinated scientific exploitation of all these data provide unique and complementary information but is a major technical challenge, since it requires accessing heterogeneous data from diverse origins in order to perform an integrated study combining different software tools appropriate for the analysis of the coupled solar wind, magnetospheric, ionospheric, thermospheric and atmospheric phenomena observed.
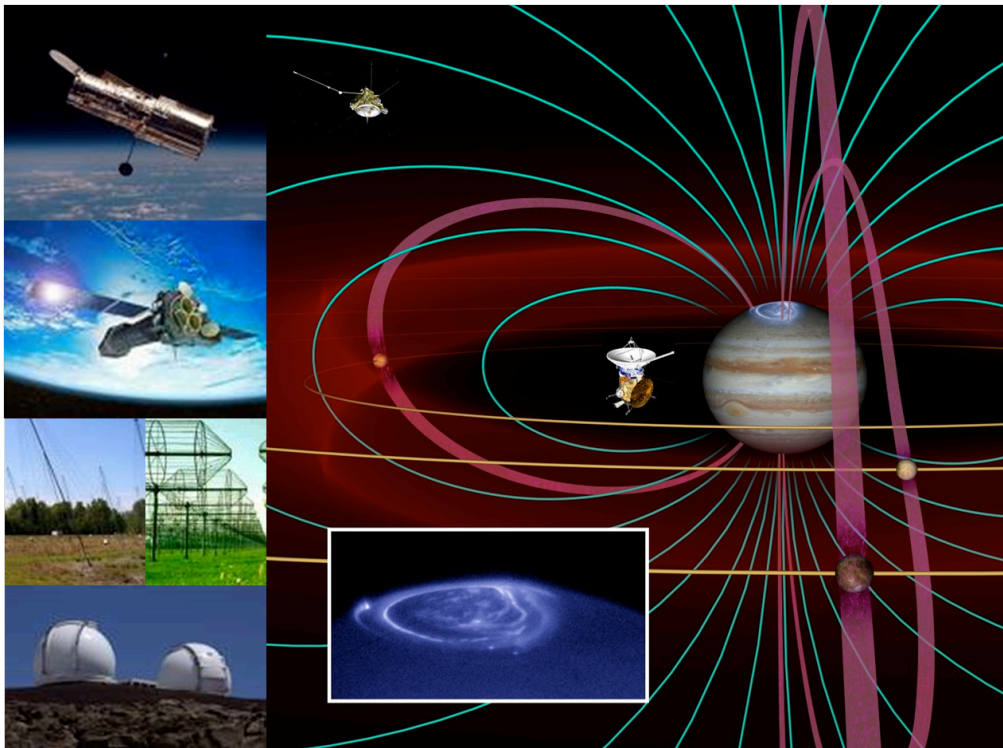

Figure 1: Schematic illustrating a coordinated network of ground- and space-based telescopes operating in various wavelengths (left panel, from top to bottom: HST (UV/VIS), XMM/Newton (X-ray), the Nançay, Kharkov (radio) and CFHT (IR) telescopes) and observing the auroral emissions of Jupiter (right panel, shown in UV from HST observations), in association with simultaneous in-situ measurements of the local solar wind and magnetospheric plasma conditions using several different spacecraft (Ulysses and Cassini/Huygens).

In the context of FP7 EuroPlaNet-RI activities, the Planetary Plasma thematic node of IDIS (http://www.europlanet-ri.eu/idis) established in close cooperation between IWF Graz and CDPP Toulouse aims to connect the CDPP/**AMDA** (Automated Multi-Dataset Analysis, http://cdpp-amda.cesr.fr/) SPASE-compatible web-based service for on-line analysis of space physics data (planetary, heliospheric, magnetospheric) together with VO interoperable tools like **Aladin** (http://aladin.u-strasbg.fr/), **VOSpec** (http://esavo.esa.int/vospec/), and **Topcat** (http://www.star.bris.ac.uk/~mbt/topcat/) used mainly by astronomical communities.

We detail in the present paper our prototype service connecting the CDPP/AMDA service with the first of the IVOA (http://www.ivoa.net/) tools mentioned above, Aladin (http://aladin.u-strasbg.fr/). All together the developed AMDA/Aladin extension provides the user with an interactive software that makes possible to visualize digitized astronomical images of Jupiter and Saturn aurorae in combination with solar wind and magnetospheric data reachable via AMDA.

PRESENTATION OF CDPP AND ITS AMDA SERVICE

The CDPP (http://cdpp.cesr.fr/, Centre de Données de Physique des Plasmas) is the french national centre for space physics data. It was jointly created by CNES (Centre National d'Etudes Spatiales) and CNRS (Centre National de la Recherche Scientifique) in 1998. Recently, the CDPP has opened a new web-based service, **AMDA** [1]. This service offers "classical" functionalities such as data extraction, merging or visualization but also innovative ones such as user-edited automated search or computation on the content of the data as well as the creation and the use of time-tables (VOTable). **AMDA** is also evolving in the Virtual Observatory paradigm. It gives a direct access to data from distant databases and includes a data access layer compliant with the SPASE (http://www.spase-group.org/) standards. Finally, **AMDA** produces, manipulates and uses time tables. The time tables can be seen as one of the primary brick to be used for the interoperable exchanges in space physics. Once registered (email amda@cesr.fr) the user has access to his/her own workspace where he/she can save his/her working sessions.
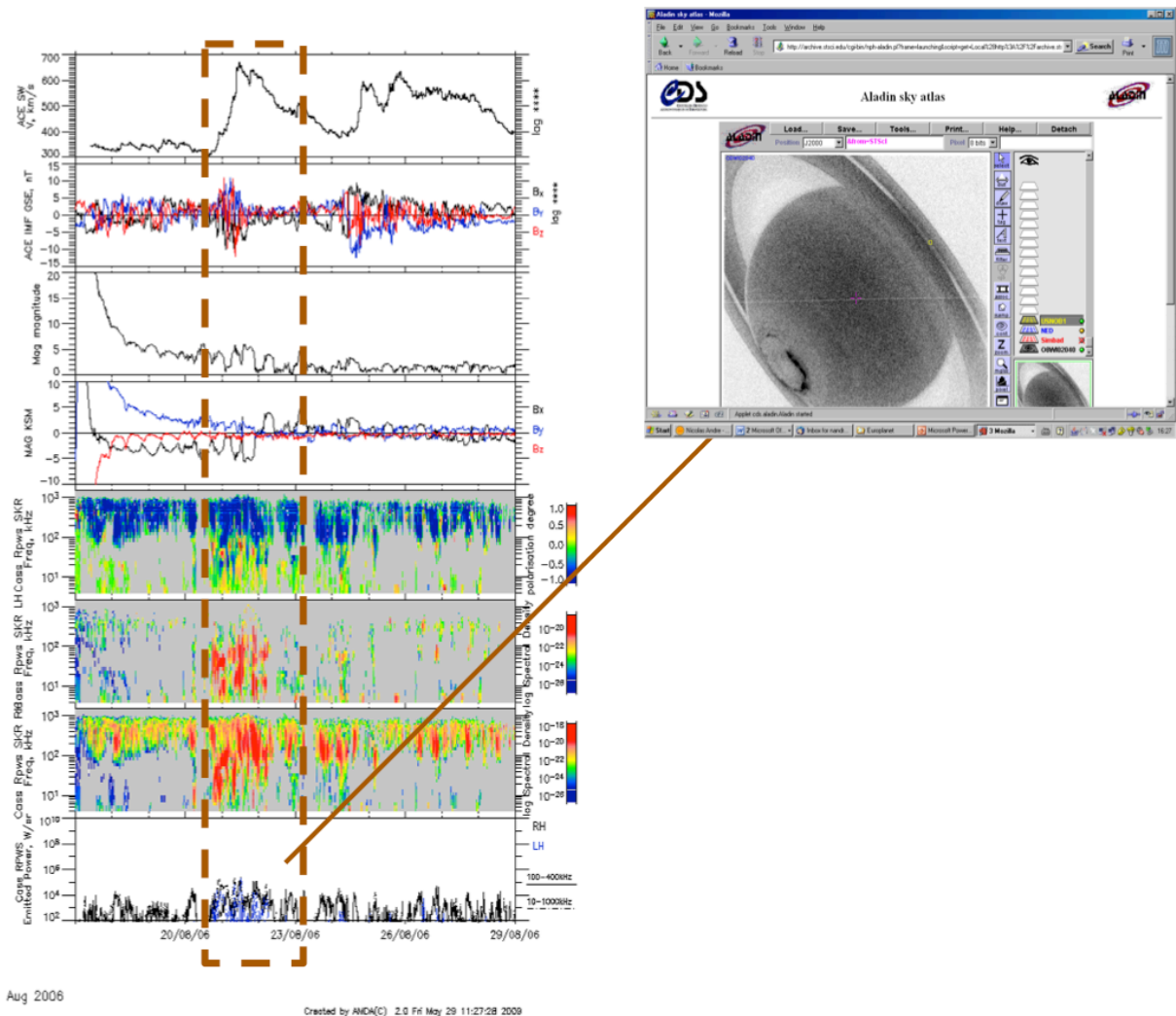

Figure 2: Summary of the foreseen AMDA/Aladin extension.

PRESENTATION OF THE IVOA CDS/ALADIN TOOL

Aladin is an interactive software sky atlas allowing the user to visualize digitized astronomical images, superimpose entries from astronomical catalogues or databases. Most of available image and catalogue over the Internet are available and notably SIMBAD, NED, VizieR, MAST/STScI, CADC, HEASARC, SLOAN, NVSS, … Created in 1999, Aladin is supporting emerging standards of the Virtual Observatory. It is compliant with other visualization and analysis tools (IDL, VOPlot, TOPCAT, Specview, Splat, VOSpec ...). All these key topics allow Aladin to be a powerful data exploration and integration tool as

well as a science enabler. The Aladin Web site is : http://aladin.u-strasbg.fr. Aladin is developed by the Centre de Données astronomiques de Strasbourg (CDS). Aladin can be used directly in a Web page for dynamically visualizing astronomical data into simple navigators such as Internet Explorer or Firefox.

DEVELOPED IHM FOR THE AMDA/ALADIN EXTENSION

Objectives

The foreseen AMDA/Aladin extension should enable an AMDA user to visualize spacecraft magnetospheric observations in relation with auroral observations of giant planets taken from the Hubble space telescope HST by using the astronomer image processor Aladin. The user should be able to request HST observations for user-defined time periods, preview the existing HST observations in thumbnails, obtain scientific description about the existing observations, and visualize observations of interest with Aladin in various display modes (mosaic, movie, differences between successive observations). Figure 2 illustrates some of these objectives for the foreseen AMDA/Aladin extension.

Prerequisites

The developed AMDA/Aladin extension is still in prototype development and can be accessed for the moment at http://manunja.cesr.fr/~richard/amda/DDHTML/index.html. It will be integrated to the stable version of AMDA at http://cdpp-amda.cesr.fr in a near future.
The developed AMDA/Aladin extension depends on AMDA on one side and also on some specific java libraries. Therefore it requires the following :
- like AMDA: firefox version >= 3.5
- to run the Aladin applet and use the SAMP protocol : the latest JVM >= 1.6

SAMP (http://www.ivoa.net/Documents/latest/SAMP.html) is a messaging protocol that enables astronomy software tools to interoperate and communicate. Part of the work to develop the AMDA/Aladin extension has made use of VO-Paris Data Centre's WebSampConnector toolkit (Jérôme Berthier, IMCCE/VO-Paris). The WebSampConnector (http://vo.imcce.fr/webservices/samp/) is a faceless Java applet built upon the JSAMP implementation of the SAMP messaging protocol. It can act both as a sender and a recipient, respectively, to send notification patterns toward the VO softwares, and to receive notification patterns coming from VO softwares.

Brief IHM description

The AMDA/Aladin extension developed by Richard Hitier for CDPP relies on the following interfaces:
1. **AMDA**, where the user plots spacecraft magnetospheric observations (physical parameters),
2. **MAST**, the MultiMission Archive at Space Telescope Science Institute (http://archive.stsci.edu/), from which the user retrieves HST observations and metadatas,
3. **Aladin**, where the user plots HST observations.

The main functionality developed consists of answering to a request for HST observations between **start time** and **stop time** for a given **planet name** (either Jupiter or Saturn). To this end :
1. HST metadata are first obtained from the MAST server,
2. filters are then applied to extract the relevant datasets corresponding to the user request, and an html interface enables the user to obtain a first glance at the relevant HST observations,
3. communication is finally established with Aladin, which shows selected HST observations.

In order to give easy access to its various functionalities, the proposed html interface is organized in 3 main panels illustrated in Figure 3:
- Panel 1 **: Time Request**
presents a set of tools to control start and stop time, and run previsualization.
- Panel 2 **: Hst Images**
is the panel where the user previews and selects HST observations (images).
- Panel 3 **: Aladin Commands**

gives control to script and runs an Aladin instance with the previously selected images.

Figure 3 : Proposed html interface for the developed AMDA/Aladin extension

ILLUSTRATIONS

Visualization of spacecraft observations with AMDA

The user is supposed to run the AMDA/Aladin extension starting from AMDA. He/she first selects the relevant physical parameter in the AMDA tree and requests their visualization (function Plot Data). Figure 4 displays for example a requested plot with Cassini Saturn Kilometric Radiation observations (intensity and polarization), Cassini magnetic field observations (intensity) as well as distance to Saturn (in planetary radii) displayed as function of time for the time period 01/01/2004-31/01/2004.

Visualization of spacecraft observations with AMDA

The AMDA/Aladin extension is then run by clicking on the **Get Hst Images** button below the plot (in red on Figure 4): a new window appears with two time fields. The user can update those laters by manually selecting new start and stop times with the mouse on the plot itself.
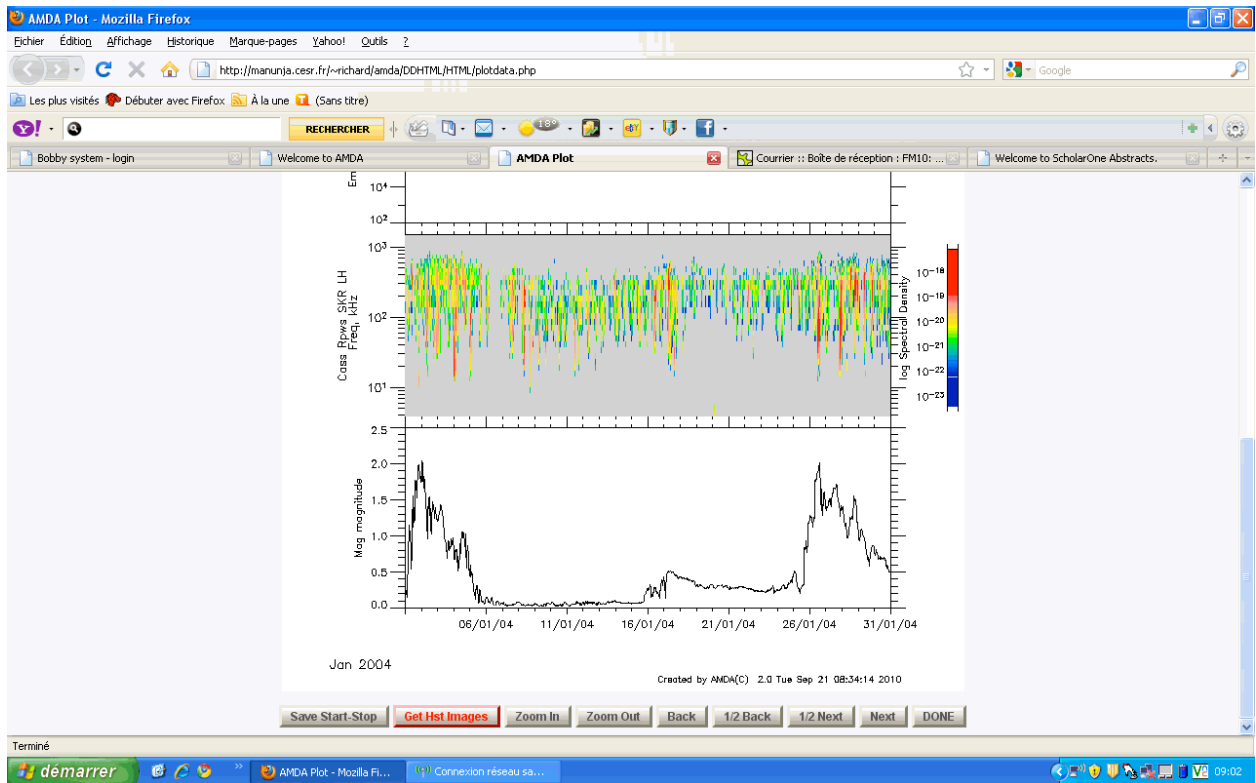
Figure 4 : AMDA plot with Cassini Saturn Kilometric Radiation and magnetic field observations obtained when Cassini was approaching Saturn during the month of January 2004. The Get HST images button appears in red at the bottom of the plot.
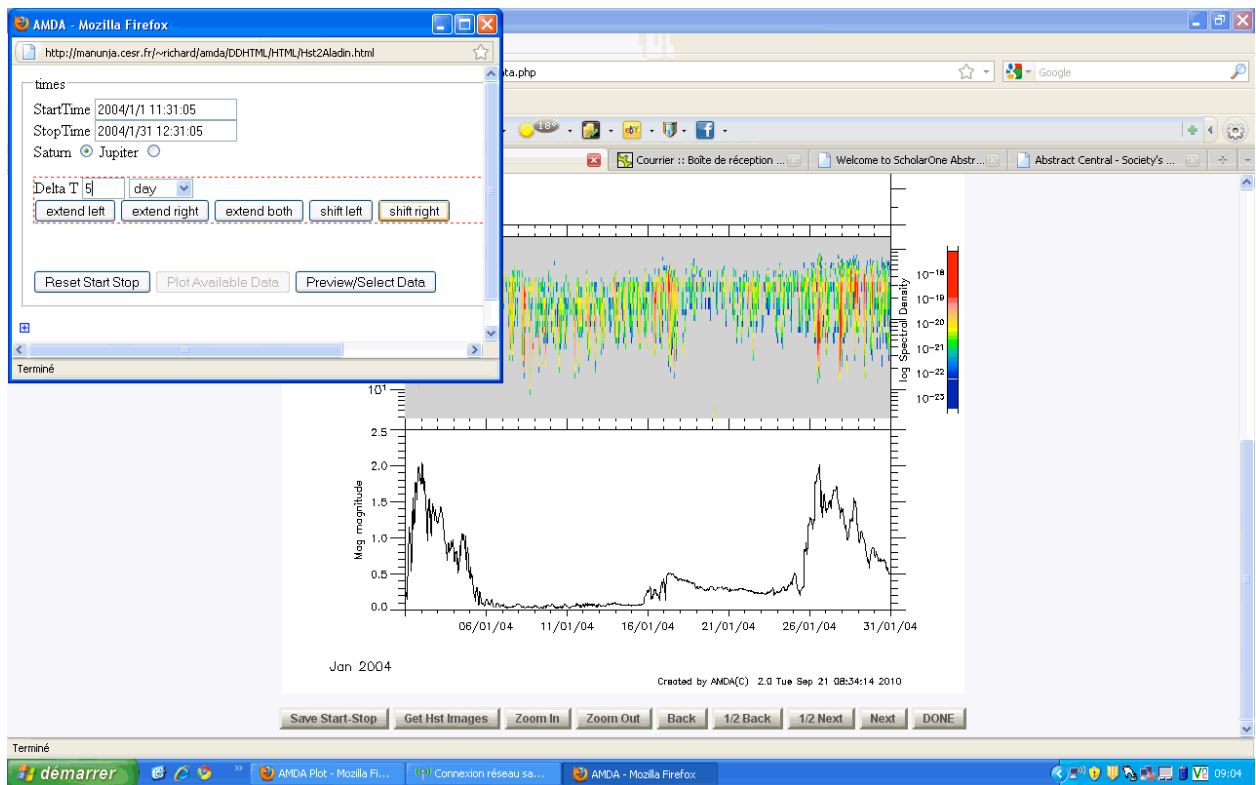

Figure 5 : Activation of the Get HST images function which opens the html interface described in the previous section.

The first panel of the newly opened html interface on the left part of Figure 5 – **Time Request** - enables the user to set the conditions for images retrieving:

- **time unit**

enables the user to define a delta T in minutes, hours, or days.

- **planet chooser**

either Saturn or Jupiter.

- **extend or shift**

enables the user to modify the start time and stop time of the time period for which he/she is requesting HST data availability, by extending the time period or shifting the time window. The last option may for example be used in order to time shift in-situ spacecraft observations in the solar wind by taking into account the distance of the spacecraft to the targeted planet.

- **reset or preview**

enables the user to reset start and stop times or refresh time settings.

Preview HST observations

After having defined all time settings in the newly opened html interface and activated the Preview/select images function, a second panel appears in the html interface – **HST Images**. It consists of a browser of the HST images corresponding to the user request. Images are sorted by date (Figure 6) and organized in day by day folders. If the requested time window is a bit too wide, the user would get a big list of available datasets, making it difficult to manage. This is why the list is splitted by day, each one being a folder that the user can open or close. One can act on each folder individually by clicking on its blue name which corresponds to the date of the day (the digit in parenthesis being the number of images for that day). All folders can be opened/close at a time with the **Open/Close Folders** button.

The user can then preview HST images by passing the mouse on the left of the dates (Figure 7) and select the images he/she want to download or visualize by ticking the box associated to each date. There are 3 possible levels for previewing or selecting images: individually, by passing the mouse on the red icon (Figure 6) or clicking on the left hand check box of the item line; all images of a day, by clicking on the icon or on the left hand check box of the whole folder line ; all images for the user request, with the **Load Previews** or **Select All** buttons.

In addition a more detailed scientific description of the HST image can be obtained directly from the MAST website by clicking on the date of the image. This option is particularly useful if the user wants to check the metadata for a specific image.

After having chosen the relevant HST images, the user can either download them in a zip file or use Aladin by activating the corresponding buttons at the bottom of this second panel.

Prepare Aladin

If the Use Aladin option is activated, a third panel in the html interface opens – **Aladin commands**. In order to use the previously selected datasets (from the second panel of hte interface) and display them in Aladin, 3 steps have to be followed :
1. set display options for Aladin,
2. build a commands script for Aladin (Figure 8),
3. send a request to Aladin for processing.

The **Aladin commands** panel is splitted into three parts.

The first one contains three buttons to define the interaction mode with Aladin (cf. Figure 3) :
- **Aladin Web** to run as an url
- **connect Aladin** to connect to a running Aladin instance,
- **Aladin Local** to send the current script to the locally running Aladin through the SAMP protocol

with a state icon that informs the user if the local connexion to Aladin was successfull.

The second one contains the script commands panel that enable the user to :
- **edit a script** for Aladin
- choose the **display mode** for Aladin:

- mosaic to show all selected images side by side, on a square grid,

- movie to show an animation built with all images,

- diff to show an animation with differences between successive images.

The third one contains the script panel itself: hidden by default, the user can show the commands to be sent by clicking on the **Aladin Script** button. This field is automatically updated when changing initial conditions: image select/unselect and Aladin display mode.

Run ALADIN

Once the user has selected the interesting HST observations and defined his/her display options, he/she can run an Aladin instance following two different modes depending on his/her needs:

Method 1 : via URL

1. Click on **Aladin Web**,

2. This method opens a link in your navigator,

3. Aladin then runs inside an applet in a new window,

4. the script is interpreted, and HST images are loaded.

This method is always available, but the user has to run a new Aladin instance each time he/she modify the script, that is to say if he/she selects/unselects images or changes the display mode (mosaic, movie or diff).

Moreover, it could be difficult to set java VM memory options, which can be useful when displaying many big images at a time.

Figure 9 provides the reader with an illustration of this method.

Method 2 : via SAMP

This way is different in that the user is supposed to already have an Aladin locally running on his/her computer. The image visualization is still controlled by the script, but the user does not need to run a new Aladin instance: this method simply sends the content of the script to a running tool through the specific SAMP protocol.

1. connect to a running instance with **connect Aladin Local**. The user should see the plugged icon as a success indicator,

2. clic on **Aladin Local** to run the command script. (in fact, it just sends the script to the running Aladin),

3. switch to the user Aladin window to see the images being loaded.

This method is faster than the previous one since :

1. Aladin is already loaded and running,

2. the user simply sends the script when it is modified.

Unfortunately, the user may run into troubles if his/her configuration is not the one expected by the library we have used (tested under firefox 3.5 and java 1.6).

CONCLUSIONS

The prototype extension of our CDPP/**AMDA** service to astronomical data (HST observations) and IVOA tools (Aladin) opens a new window in our understanding of comparative auroral and magnetospheric physics of giant planets and will enhance the scientific return of previous, current and future (e.g., NASA/Juno) planetary missions to these environments. Our extended service will ultimately serve and benefit the European planetology community (and beyond) as well as promote and enlarge the application domain of astronomical VO tools. Also, this consists of one of the first experiment to combine tools at the interface of the plasma (SPASE) and astronomy (IVOA) communities.
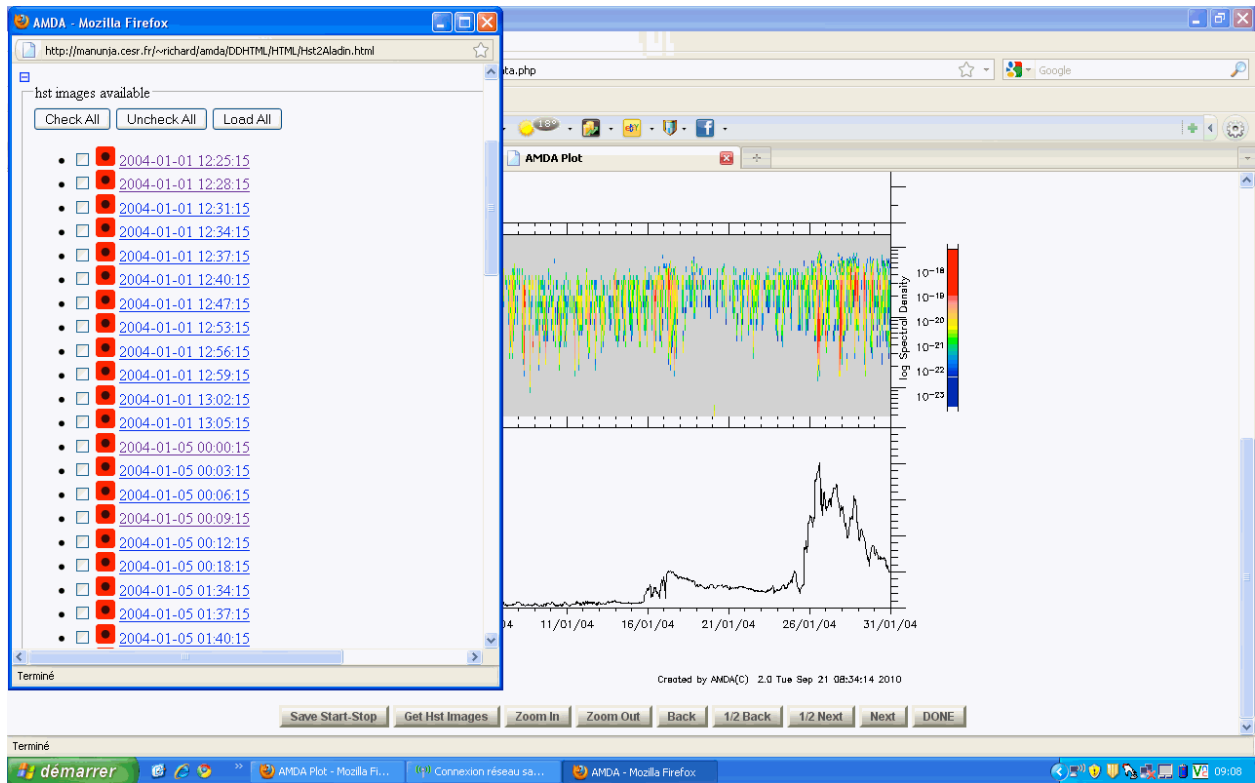
Figure 6: List of available HST images for the user-defined time periods. They are organized by dates. Empty and red boxes enable the user to choose the relevant images or preview them.
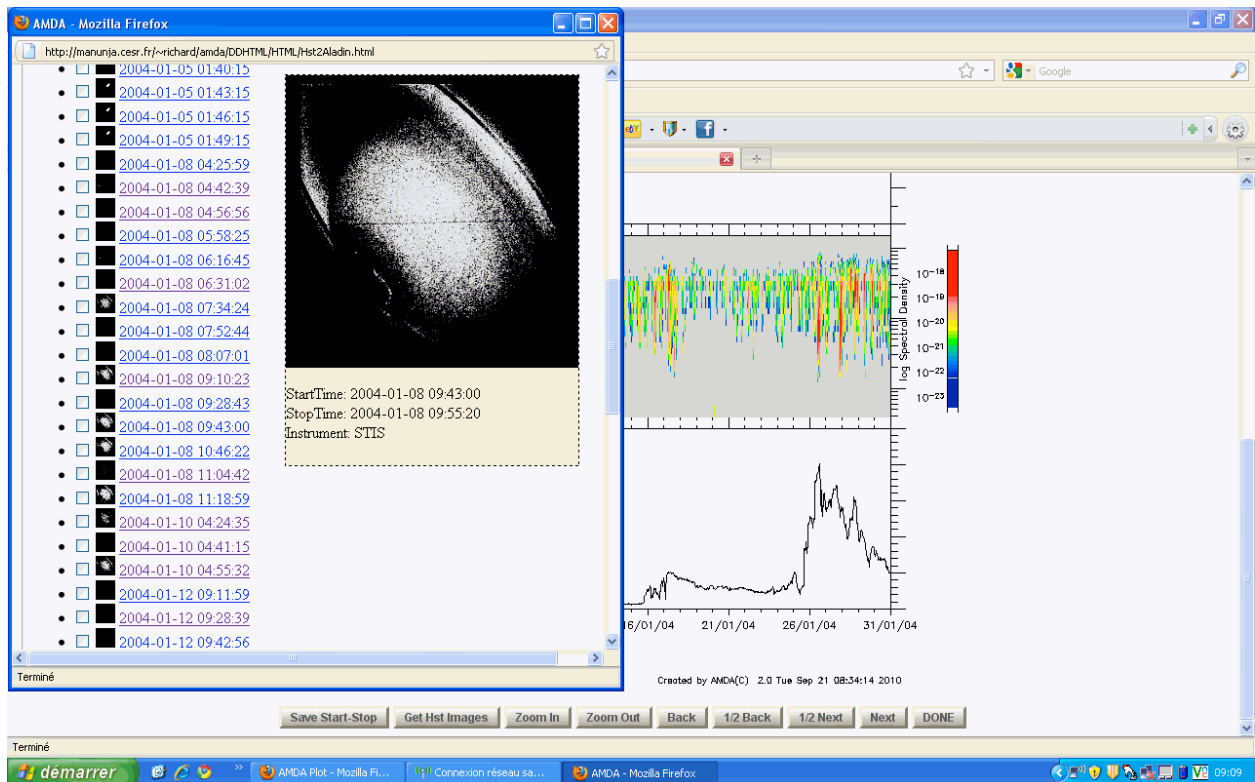

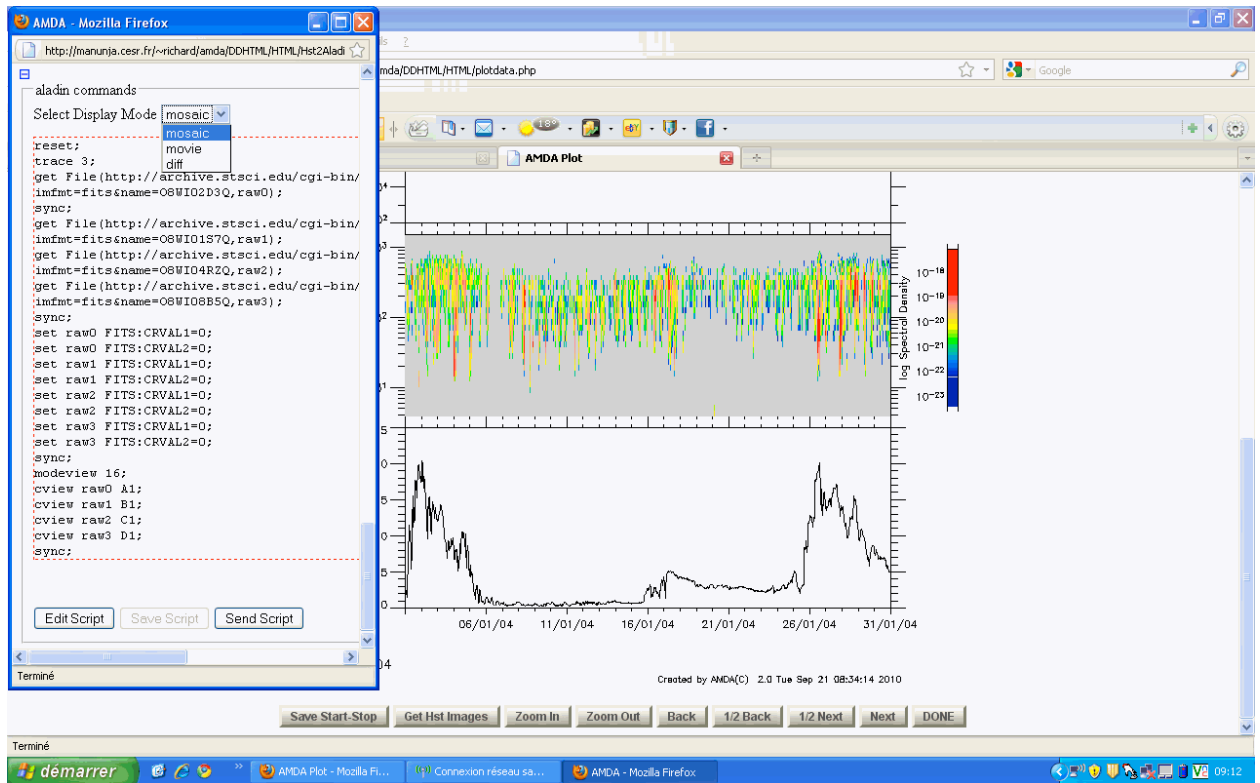Figure 7: Example of a preview for an HST image obtained by the STIS instrument on a specific date.

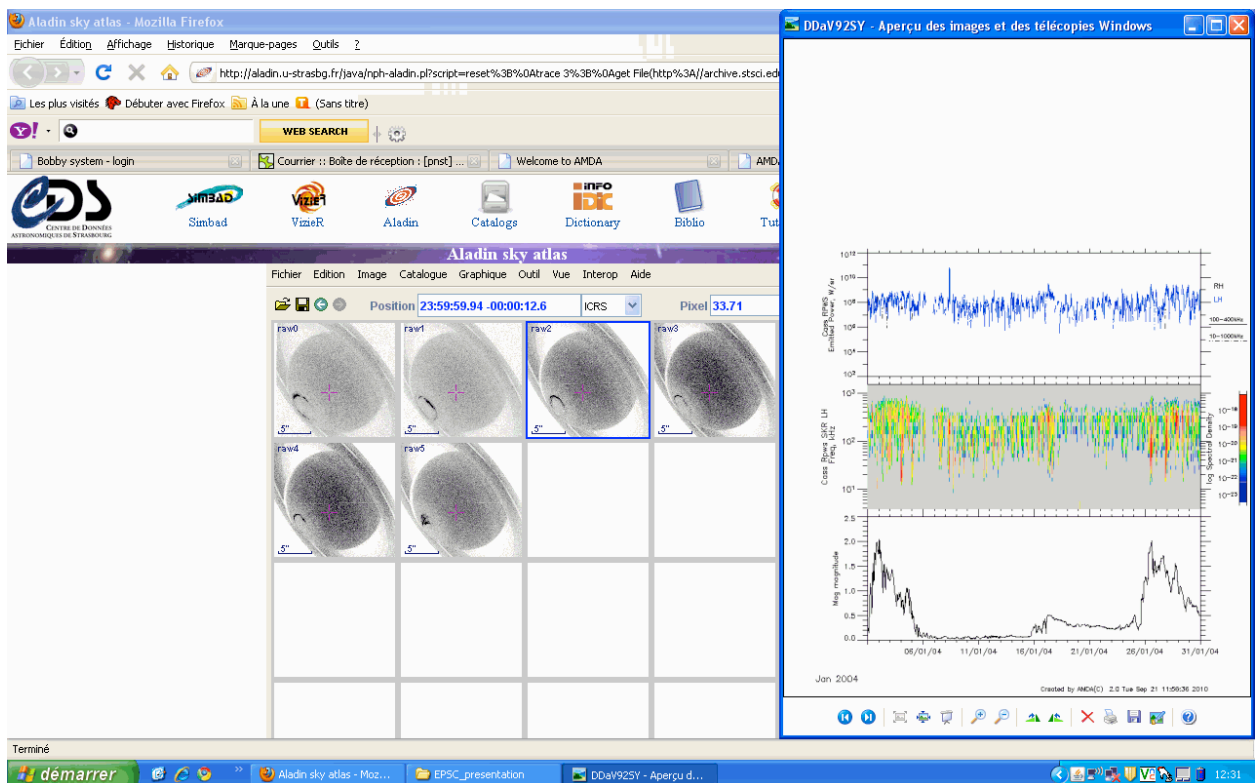Figure 8: Display options and script to be sent to Aladin

Figure 9: Visualization of HST observations in Aladin (left, mosaic mode, via URL), in relation to spacecraft observations displayed in AMDA (right).

REFERENCES

[1] - C. Jacquey, V. Génot , E. Budnik , R. Hitier , M. Bouchemit , M. Gangloff , A. Fedorov , B. Cecconi, N. André , B. Lavraud , C. Harvey , F. Dériot , D. Heulet, E. Pallier , E. Penou and J.L. Pinçon, AMDA, Automated Multi-Dataset Analysis: A web-based service provided by the CDPP. The Cluster Active Archive, Studying the Earth's Space Plasma Environment. Edited by H. Laakso, M.G.T.T. Taylor, and C. P. Escoubet. Astrophysics and Space Science Proceedings, Berlin: Springer, 2010, p.239-247.